

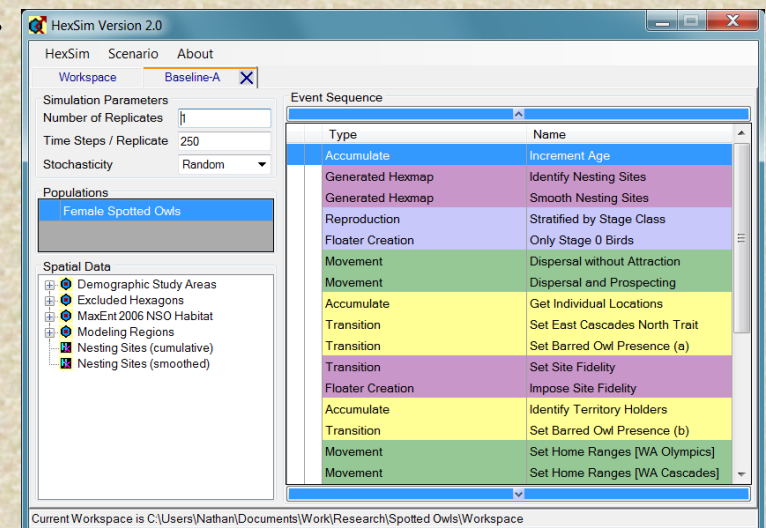
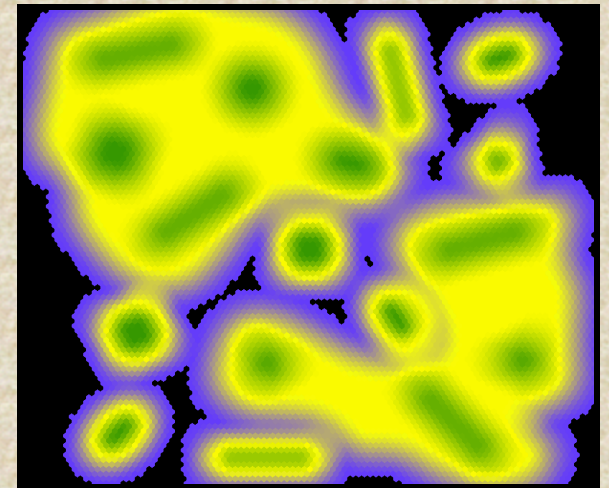


# An Introduction to the HexSim Model

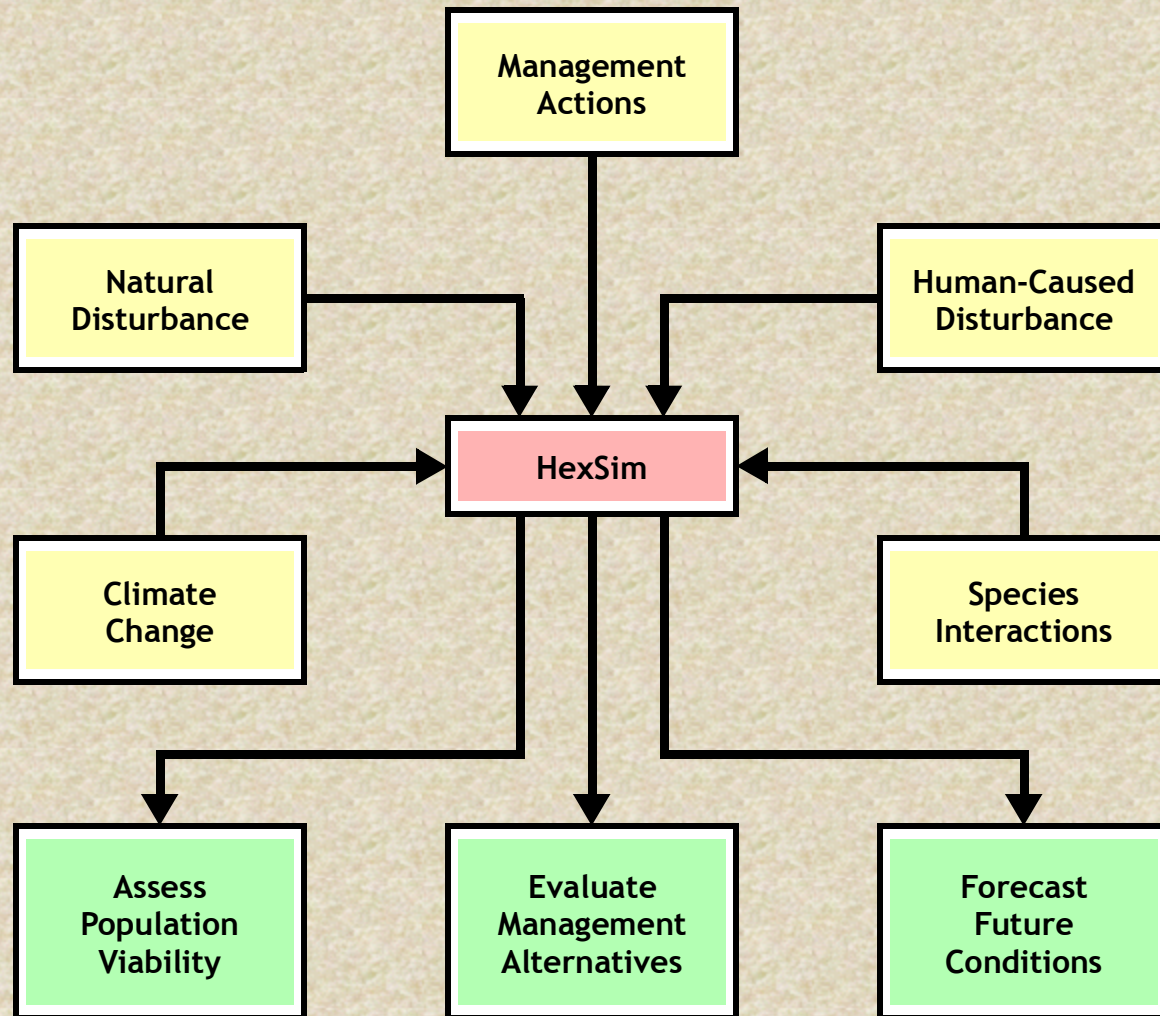
Nathan H. Schumaker

# What is HexSim?

- It is a computer simulation model.
- It was designed for evaluating wildlife population responses to human activities.
- It balances generality and flexibility with parsimony and ease of use.
- It can be used with a large range of places, problems, and questions.



# Using HexSim in Ecological Research



# Significant Challenges

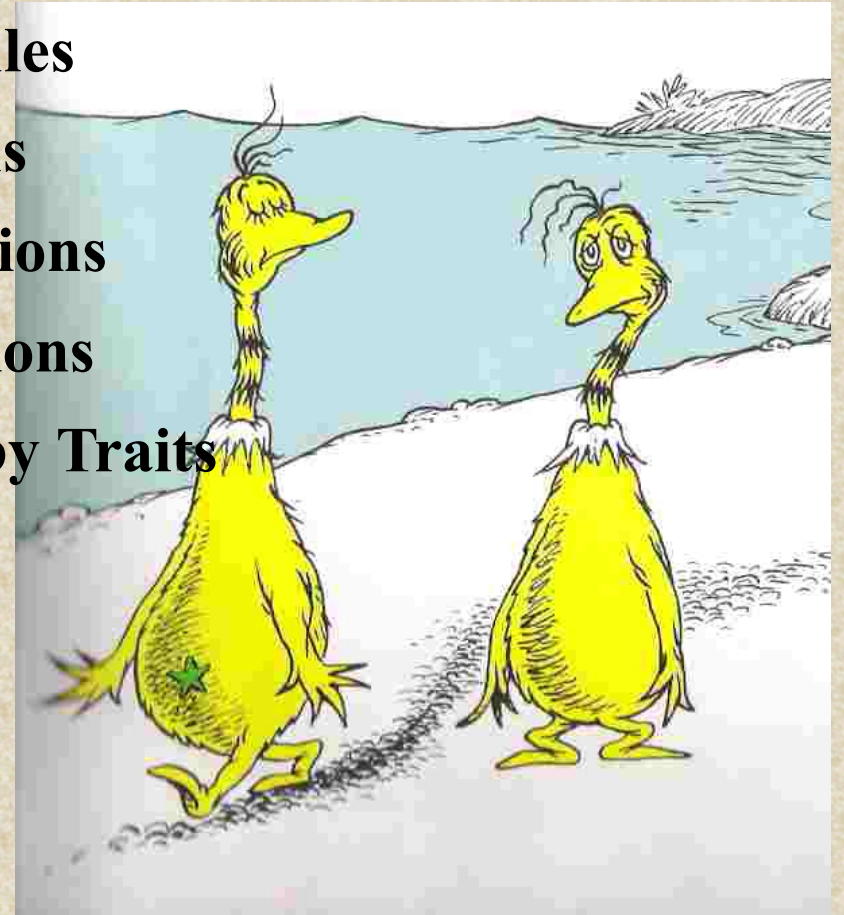
- ➔ **Landscapes.** They are dynamic; structure matters; features change with life history
- ➔ **Populations.** They have complex, diverse life histories, and can interact
- ➔ **Disturbance.** Can vary in space and time; there can be multiple; they often interact
- ➔ **Methodology.** Must be defensible and usable, plus have value to decision-makers

## **How is HexSim Different?**

- It has a wide range of potential applications.**
- It contains no simplifying assumptions about the biology or ecology of the study systems**
- Every individual can have unique properties that change throughout their lifetimes**
- Can simulate population interactions, stressor interactions, landscape genetics, and more**
- Modern and easy to use, with graphical user interfaces (GUI) for every model component**

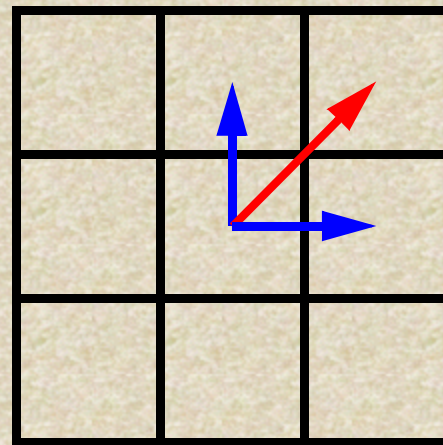
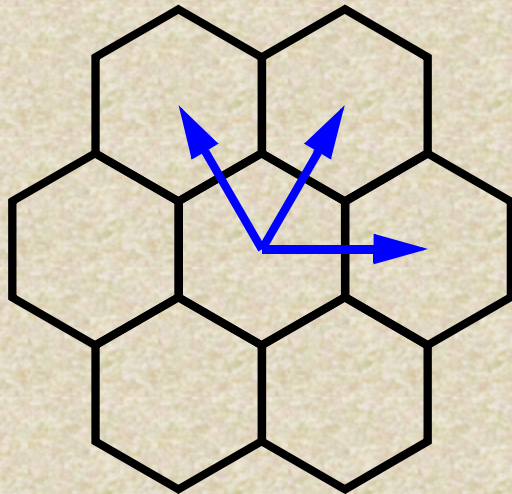
# HexSim Fundamentals

- ➔ Spatially-Explicit and Individual-Based
- ➔ Landscapes can Change Continuously
- ➔ No Built-In Assumptions or Rules
- ➔ Multi-Stressor with Interactions
- ➔ Multi-Population with Interactions
- ➔ Females-only or 2-Sex Simulations
- ➔ Life History Events Stratified by Traits



# Why Hexagons?

- ➔ They provide a space-filling tessellation
- ➔ Each of a hexagon's neighbors is the same distance away.



# Model Inputs

- **Spatial Data.** Can be real or fabricated, one or multiple layers, static or time series...
- **Life History Data.** Can be real or fabricated or a hybrid. Data limits model complexity...
- **Disturbance Regimes.** Spatial, temporal, simple, complex, local, regional, etc...
- **Stochasticity.** Demographic, environmental, life stage-specific, spatially-distributed, etc...

# Model Outputs

- ➔ **Census Data.** Chronological records of user-defined population metrics.
- ➔ **Tabular Reports.** CSV files detailing observed vital rates, movements, interactions, etc.
- ➔ **Map-Based Reports.** Map files illustrating population performance and interactions.
- ➔ **Videos.** Movies showing movement, resource acquisition, occupancy by trait class, etc.

# Life History Events

- ➔ Survival
- ➔ Reproduction
- ➔ Movement
- ➔ HexMap Generation
- ➔ Species Interaction
- ➔ Species Introduction
- ➔ Mutation
- ➔ And so on...

# Trait Types

- ➔ Probabilistic Traits
- ➔ Accumulated Traits
- ➔ Genetic Traits

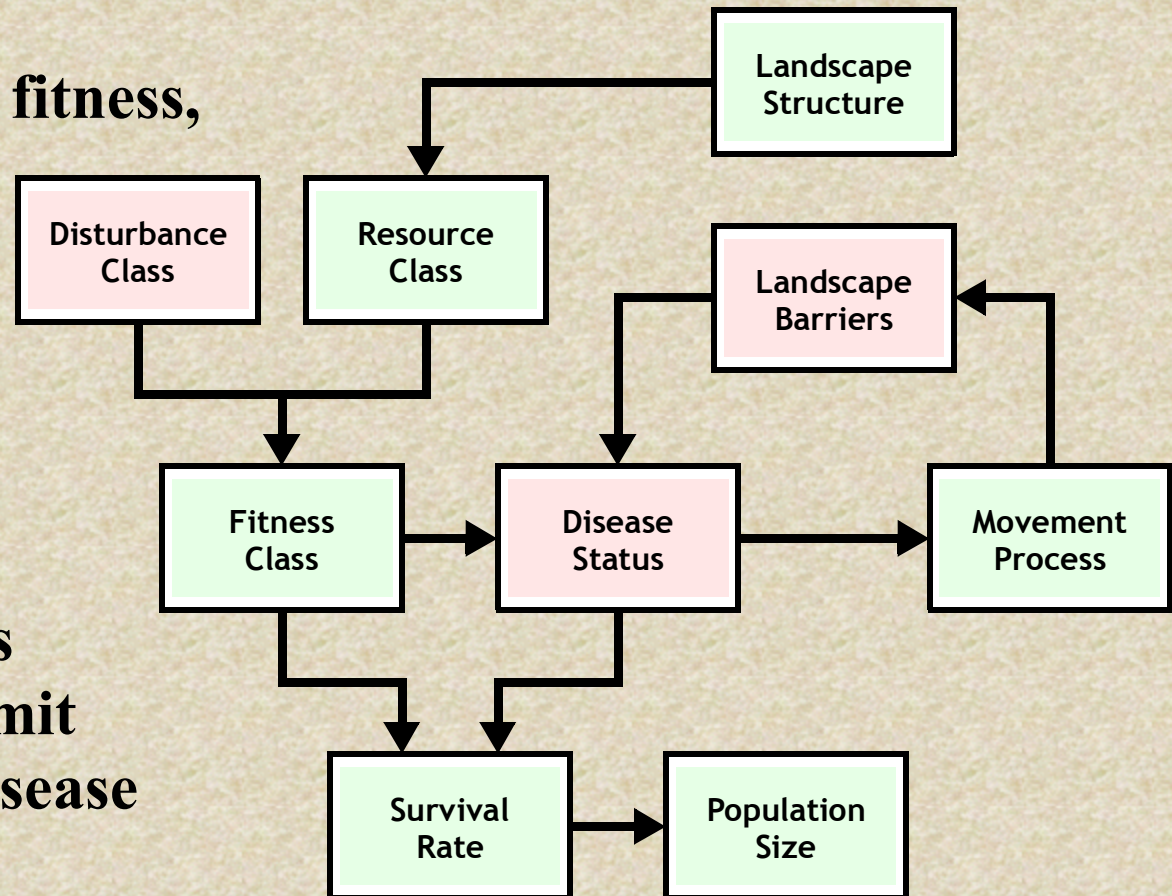
Survival ⇒ Combinations ↓	Mean Rate
▶ Juvenile	0.7
Subadult	0.8
Adult	0.9

Births ⇒ Combinations ↓	0	1	2	3	4	5	6	Expected Value
▶ Female, Juvenile	1	0	0	0	0	0	0	0
Female, Adult	0	0.1	0.1	0.2	0.3	0.2	0.1	3.7
Male, Juvenile	1	0	0	0	0	0	0	0
Male, Adult	1	0	0	0	0	0	0	0

# A Hypothetical HexSim Scenario of Moderate-Complexity

■ Disturbance affects fitness, which in turn impacts disease status, survival, and reproduction

■ Movement barriers affect survival rates because they can limit the spread of the disease



# HexSim Genetics

- ➔ Each individual is assigned a genotype
- ➔ Populations can have any number of loci
- ➔ Each locus can have any number of alleles
- ➔ Inheritance can be from mother, father, or from both parents (per locus)
- ➔ User-defined initial conditions, include spatial stratification of alleles

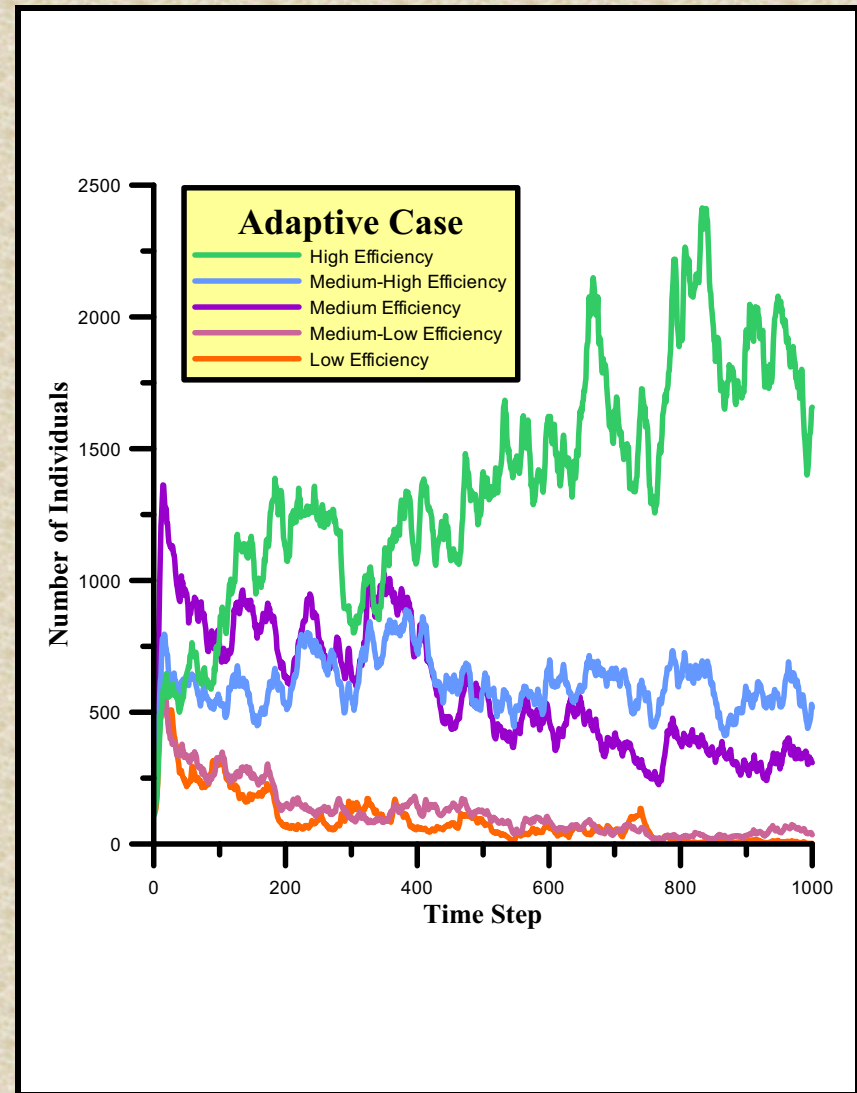
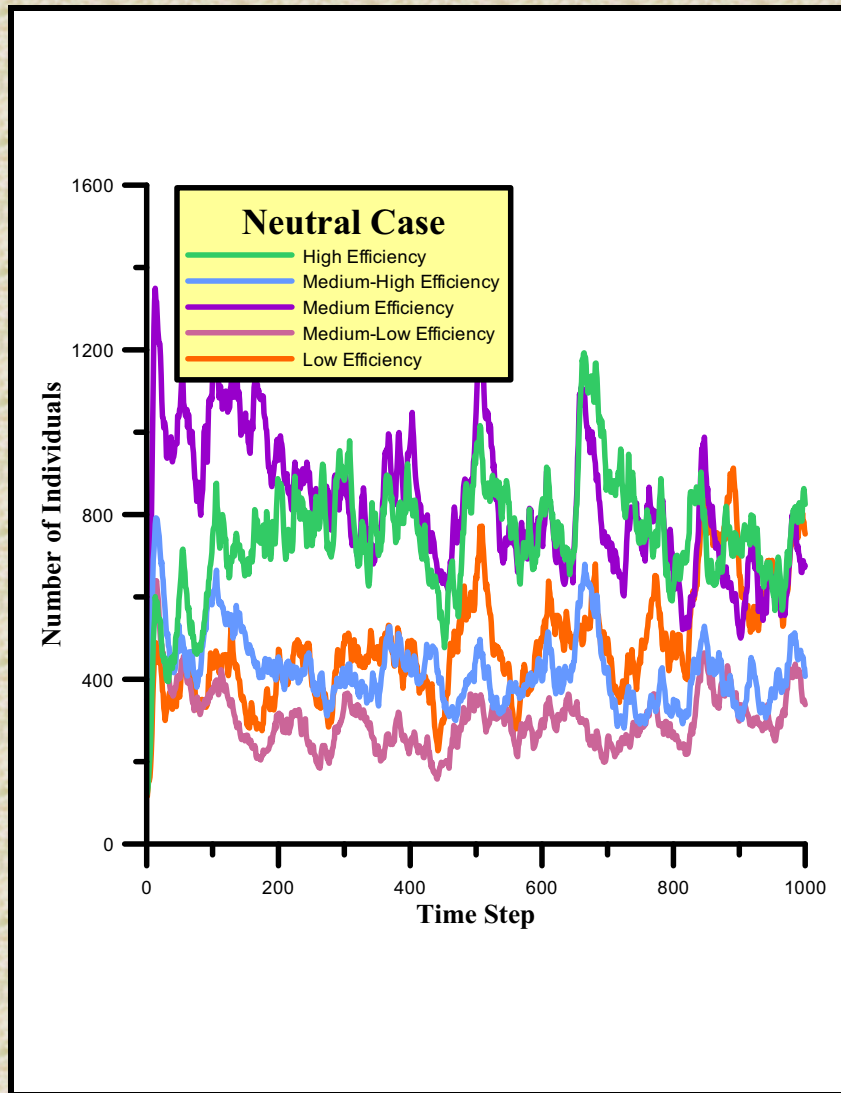
## HexSim Genetics (cont.)

- ➔ Mutation events may be influenced by non-heritable traits (e.g. exposure)
- ➔ Heritable traits may be neutral or adaptive
- ➔ Heritable and other traits may be combined to influence life history events
- ➔ Map-distances may be used to simulate chromosome crossover

## **Example: Predators & Prey**

- Two interacting populations**
- Predators & prey use different mating schemes**
- Prey live in colonies, predators do not**
- Predator males disperse towards prey  
Predator females disperse towards males**
- Predator capture efficiency is controlled through a heritable trait.**
- Capture efficiency influences reproduction through a resource acquisition trait**
- Mutation alters capture efficiency trait**

# Allele Frequencies



# Some PATCH / HexSim Applications

- ➔ **Ord's Kangaroo Rats**
- ➔ **Spotted Owls**
- ➔ **Kit Foxes**
- ➔ **Lyme Disease**
- ➔ **Pileated Woodpeckers**
- ➔ **Desert Tortoise**
- ➔ **Black-capped Vireos / Cowbirds**
- ➔ **Elk**
- ➔ **Wolves**
- ➔ **Fishers**
- ➔ **Martin**

# Ord's Kangaroo Rats (Alberta)



# Feasibility Assessment for Reintroducing Fishers to Washington

by Jeffrey C. Lewis and  
Gerald E. Hayes



Washington Department of  
**FISH AND WILDLIFE**  
Wildlife Program

# Fisher Reintroduction

Table 13. Median number of female fishers predicted by the PATCH model to be supported on potential reintroduction areas in the Olympic Peninsula, Northwestern Cascades, and Southwestern Cascades. Values were derived from 20 replicate simulations started with 30, 60 and 100 female fishers; male presence is assumed in the model.

Simulation specifications		Median number of female fishers supported		
Leslie matrices used <sup>1</sup>	Simulation length	Olympic Peninsula	Southwestern Cascades	Northwestern Cascades
<b>30 Females Reintroduced</b>				
Single Mean	20 years	82.5	36	25
	40 years	94	33.5	19.5
Six Random	20 years	81.5	35	17
	40 years	84.5	29.5	17
<b>60 Females Reintroduced</b>				
Single Mean	20 years	93.5	48	26.5
	40 years	92	36.5	21
Six Random	20 years	90.5	49.5	27.5
	40 years	87.5	25	21
<b>100 Females Reintroduced</b>				
Single Mean	20 years	98.5	59.5	31
	40 years	96	43.5	20
Six Random	20 years	102	54.5	30.5
	40 years	87	44.5	23.5
<b>100 Females Reintroduced, additional specifications for sensitivity testing<sup>2</sup></b>				
Single Mean, 25 km maximum dispersal	20 years	101.5	57.5	32
	40 years	97.5	48	24
Single Mean, 75 km maximum dispersal	20 years	98.5	55	30
	40 years	96	40	22.5
Single Mean, low habitat scores	20 years	50.5	6	4.5
	40 years	51.5	0	0

<sup>1</sup> Two matrix scenarios were used in simulations. The single mean simulations were run with 1 Leslie matrix with mean values for survival and fecundity. The six random matrix simulations used four matrices of mean survival and fecundity values, one matrix with low values, and one matrix with high values; one of these six matrices was chosen at random each year of a simulation to incorporate environmental stochasticity.

<sup>2</sup> Three alternative simulations were run to test the sensitivity of the model to: a smaller maximum dispersal distance of 25 km, a larger maximum dispersal distance of 75 km, and lower habitat scores for suboptimal habitats.

# Baseline Evaluation of Fisher Habitat and Population Status & Effects of Fires and Fuels Management on Fishers In the Southern Sierra Nevada

## Prepared By:

Wayne Spencer  
Heather Rustigian  
Robert Scheller  
Alexandra Syphard  
James Strittholt  
Brendan Ward

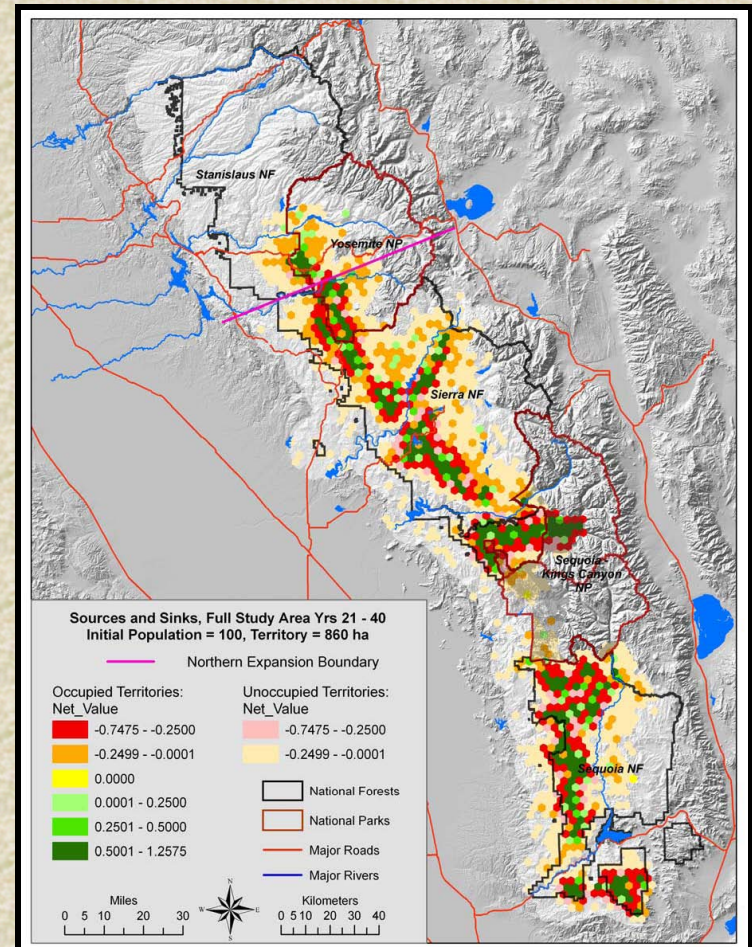
## Prepared For:

USDA Forest Service, Pacific Southwest Region



June 2008

# Fisher Dynamics in the Sierra Nevada



U.S. Fish & Wildlife Service

## 2010 Draft Revised Recovery Plan for the Northern Spotted Owl (*Strix occidentalis caurina*)

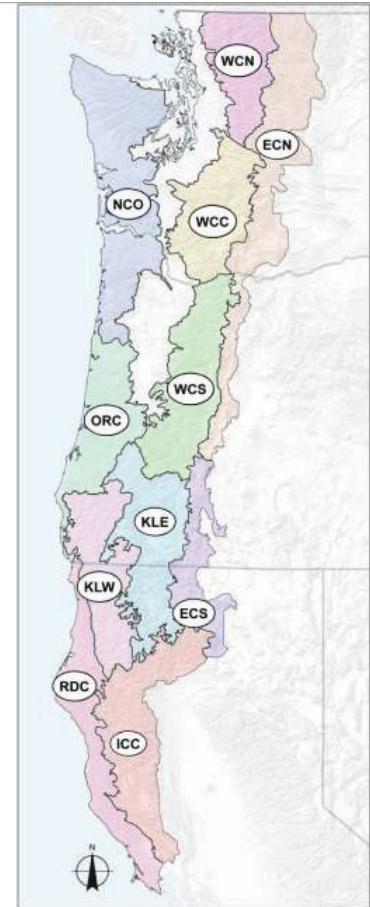


# Spotted Owl Recovery

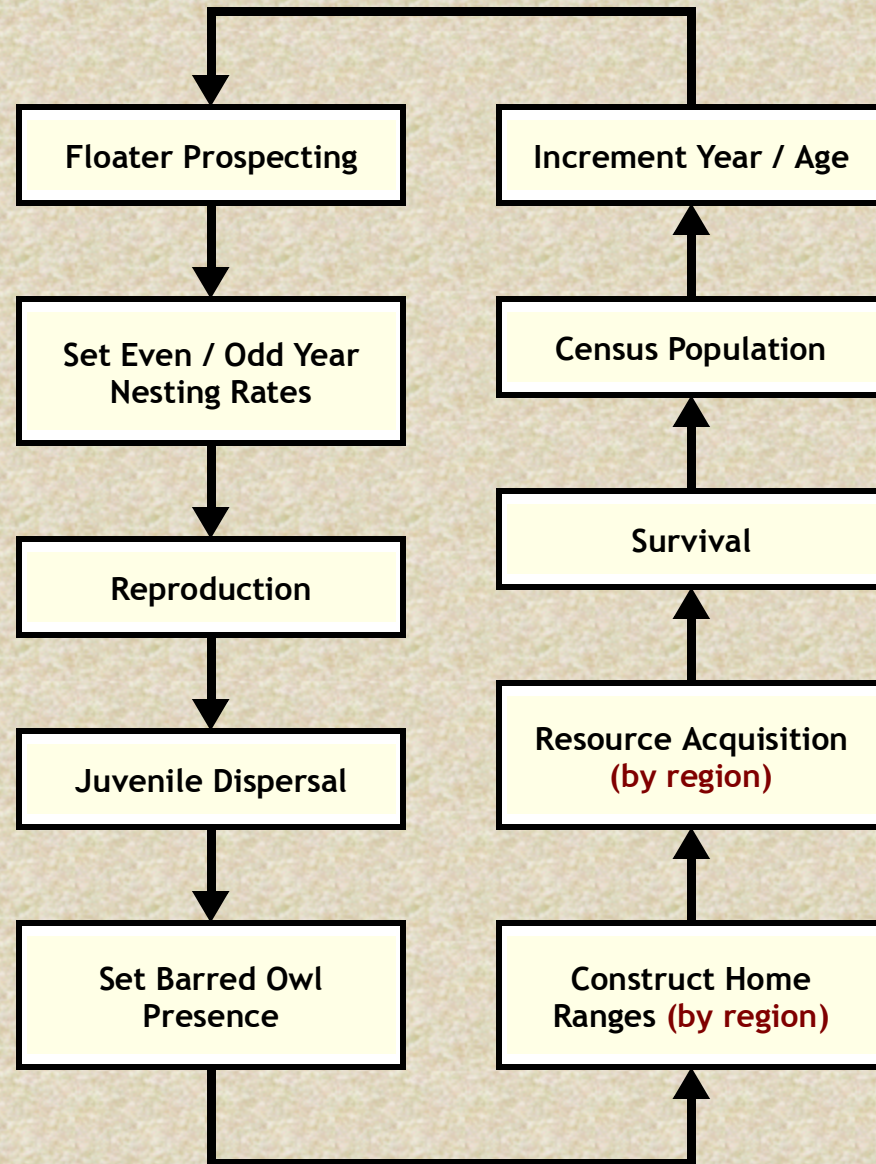
## Modeling Regions

CODE	DESCRIPTION
NCO	North Coast and Olympic
ORC	Oregon Coast
ECS	Eastern Cascades - South
ECN	Eastern Cascades - North
WCN	Western Cascades - North
WCC	Western Cascades - Central
WCS	Western Cascades - South
KLE	Klamath-Siskiyou - East
KLW	Klamath-Siskiyou - West
ICC	Interior California Coast
RDC	Redwood Coast

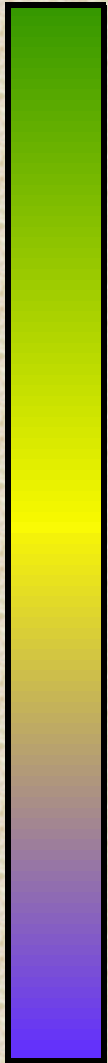
No warranty is made by the U.S. Fish and Wildlife Service as to the accuracy, reliability, or completeness of these data for individual or aggregate use with other data. Original data were compiled from various sources; spatial information may not meet National Map Accuracy Standards. This information may be updated without notification.



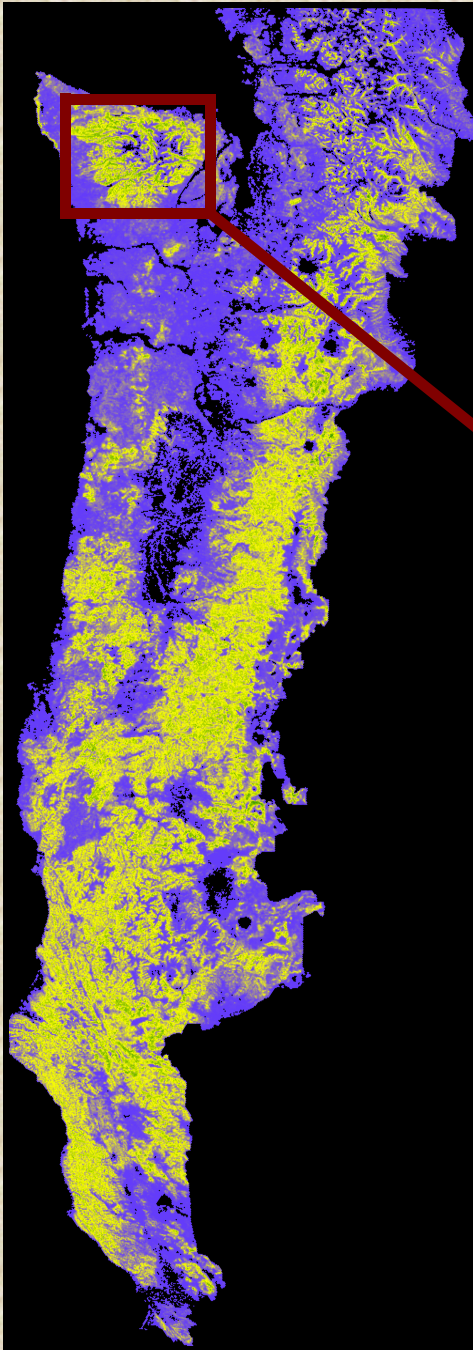
# Simulated Spotted Owl Life Cycle



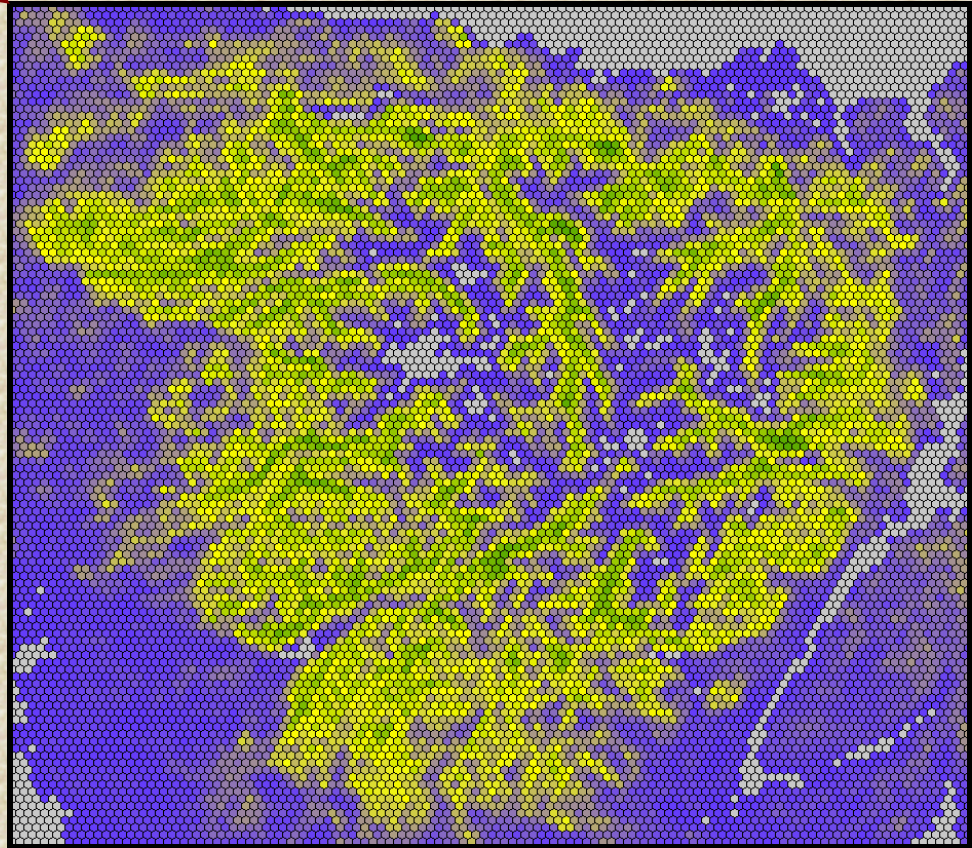
Highest  
Quality



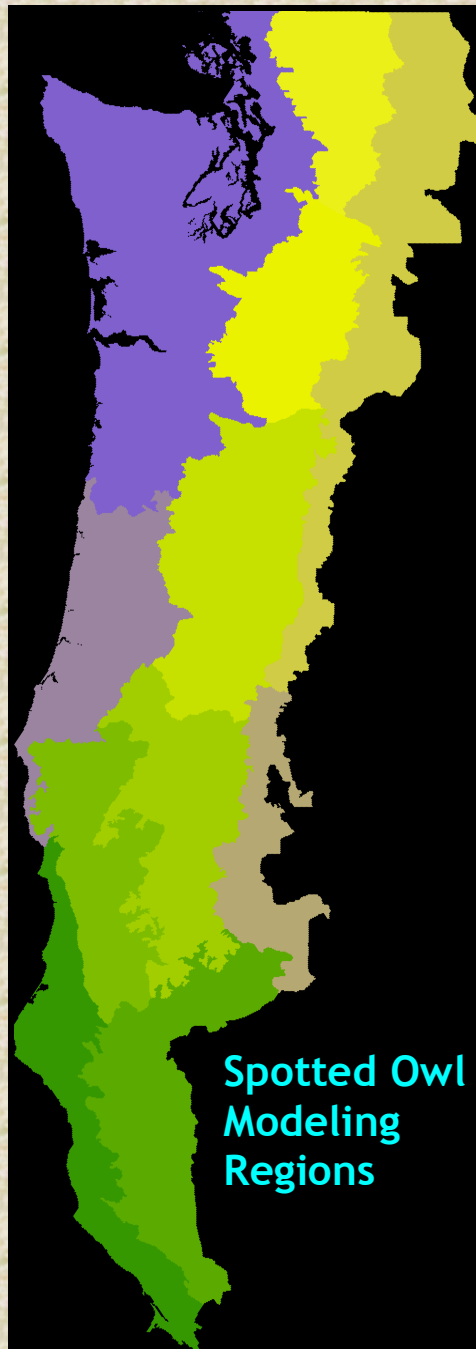
Lowest  
Quality



## MaxEnt Current Conditions Resource Map



# Process Varies with Location



Range Spatial Data    MaxEnt 2000 NSO Habitat

Range Barriers

Maximum Range Area

Maximum Range Span

Maximum Group Member

Hexagons Range-Eligible

Minimum Range Resource

Floater Preemption of Group

☐ Competitive Ability (%)

Resource Targets

☐ Barred Owl Present

☐ Demographic Study

☒ Modeling Region

☐ Resource Class

☐ Stage Class

☐ Territory Status

Transition	Set Barred Owl Presence (b)
Movement	Set Home Ranges [WA Olympics]
Movement	Set Home Ranges [WA Cascades]
Movement	Set Home Ranges [OR Cascades]
Movement	Set Home Ranges [OR Coast Range]
Movement	Set Home Ranges [OR Klamath]
Movement	Set Home Ranges [CA Klamath]
Movement	Set Home Ranges [CA Redwood]
Accumulate	Acquire Resources

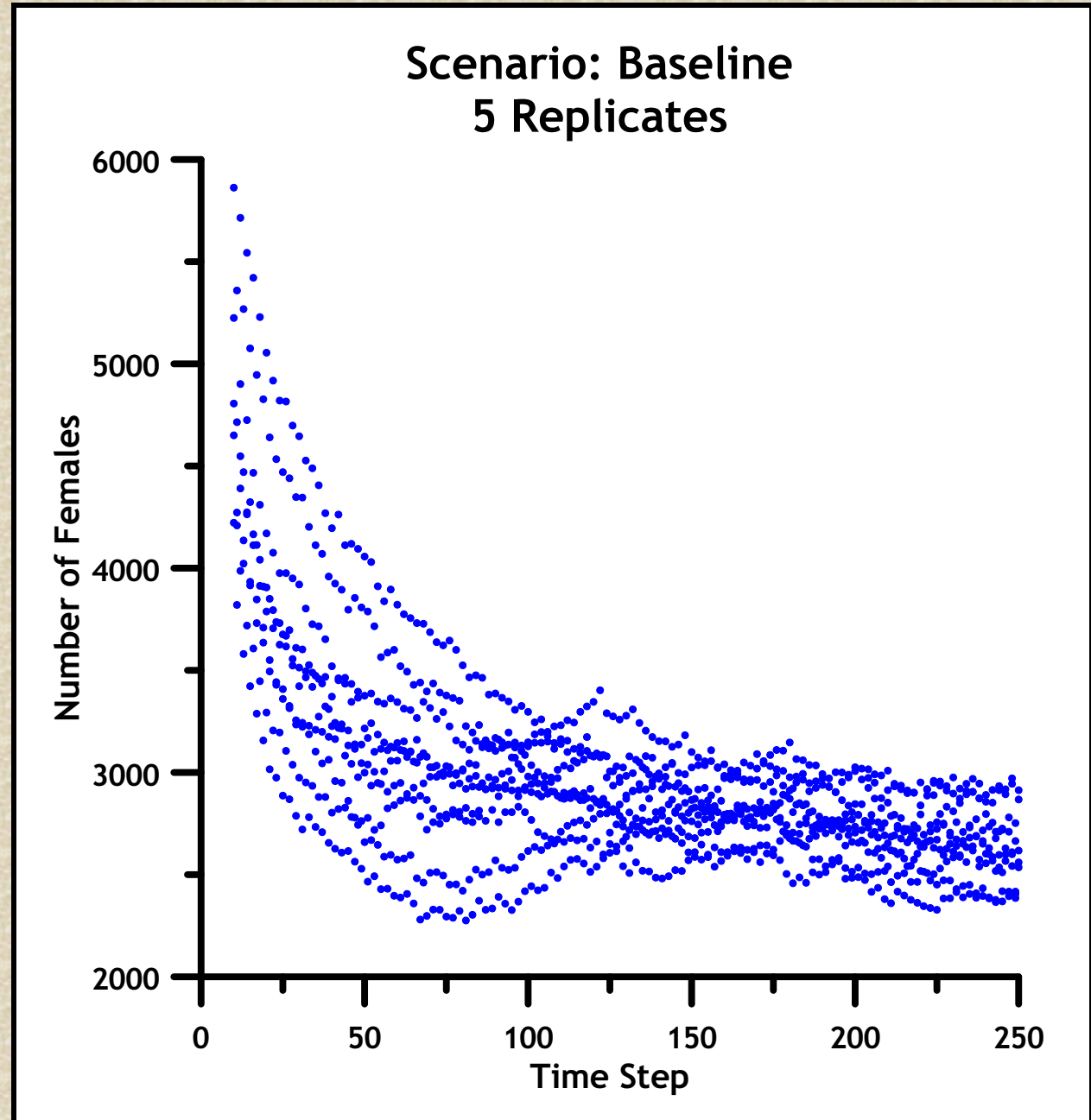
Name	Rank	Target
Not In A Modeling Region	0	0
North Coast Olympics	0	1250
Oregon Coast	0	375
East Cascades South	0	750
East Cascades North	0	1000
West Cascades North	0	1250
West Cascades Central	0	1250
West Cascades South	0	375
Klamath East	0	375
Klamath West	0	375
Inner California Coast Ranges	0	375
Redwood Coast	0	250

Import

Recover    Close

## Results

### Total Population Size



# Results

## Population Size by Region

